VUF-1027
FINAL REPORT

VELA UNIFORM PROGRAM

PROJECT DRIBBLE

SALMON EVENT

TATUM SALT DOME, MISSISSIPPI

22 OCTOBER 1964

part of an experiment in seismic decoupling at the nuclear level

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Ground-Water Safety

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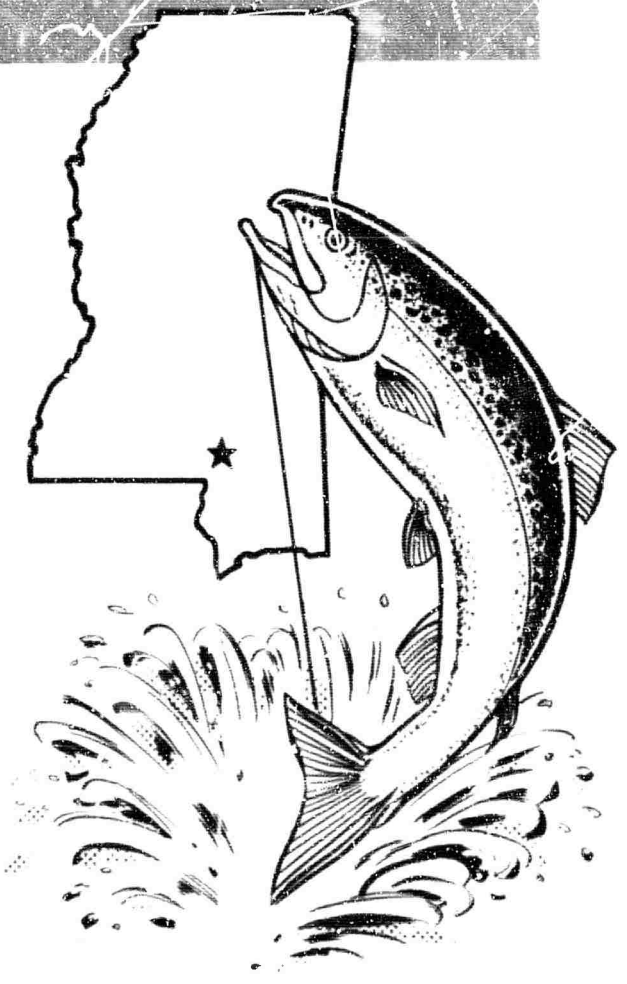

Earth Sciences Division
HAZLETON-NUCLEAR SCIENCE
CORPORATION

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PROJECT DRIBBLE

Final Report

GROUND-WATER SAFETY

SALMON EVENT

October 1, 1965

Earth Sciences Division
HAZLETON-NUCLEAR SCIENCE CORPORATION
Palo Alto, California

CONTENTS

ABSTRACT

Evaluations, predictions, and recommendations for ground-water safety were made for the 5 kiloton Salmon Event, Project Dribble.

Pre-shot consideration indicated that the nuclear explosion would be fully contained within the salt mass of Tatum Dome, enabling the conclusion that radiocontamination of aquifers intersecting or overlying Tatum Dome would not occur. In the unlikely event that contaminants were introduced into aquifers it was estimated that contaminant movement within the aquifers would be limited to a maximum lateral distance of about 700 meters from the point of insertion before reduction to acceptable concentrations by radioactive decay. Recommendations were included to examine several lines of shot and post-shot evidence to evaluate the possibility of ground-water contamination as a result of the detonation.

The shot and post-shot data indicate that the Salmon underground nuclear event was essentially contained within the salt matrix of Tatum Dome and no explosion radioactivity has been detected in the aquifers.

Recommendations are made for future sampling and monitoring of all aquifers previously considered to assure continuing ground-water safety.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Hazleton-Nuclear Science Corporation (H-NSC) under contract No. AT(29-2)-1229 with Nevada Operations Office, U. S. Atomic Energy Commission is responsible for evaluation of ground-water safety of underground nuclear tests. The work reported herein was conducted as part of this responsibility.

Salmon Event, Project Dribble, was the detonation of a five kiloton nuclear device at a depth of 823 meters within Tatum Salt Dome, Lamar County, Mississippi on October 22, 1964. The possible contamination and disruption of ground-water supplies in relatively shallow fresh-water aquifers which intersect and overlie Tatum Dome is the principal concern to ground-water safety associated with the Salmon Event.

This report reviews pre-shot ground-water safety activities of Hazleton-Nuclear Science Corporation and summarizes shot results and post-shot information from operational agencies, as available. The current status of ground-water safety is discussed and recommendations are made for additional efforts required to assure continuing safety of ground-water supplies.

CHAPTER 2

SAFETY PREDICTIONS

2.1 GEOLOGIC-HYDROLOGIC ENVIRONMENT

Tatum Dome is a shallow piercement-type salt stock, which intersects sedimentary deposits of early Cretaceous to Oligocene age and is overlain by sediments of Miocene age. The Tertiary sediments have a regional dip of about 7.6 meters per kilometer to the southwest except where modified by the salt stock or other local structural features. At surface zero the depth to the top of the caprock overlying the salt is 309 meters and the salt contact is encountered at 448 meters. Surface zero is 74 meters above mean sea-level. Radial or circumferential faulting within or immediately surrounding the salt mass was not revealed in the pre-shot seismic and drilling investigations.

In the vicinity of Tatum Dome eight aquifers 15 meters or more thick are recognized, extending to a depth of about 790 meters. In descending order "local" aquifer and Aquifers 1, 2a, 2b, and 3a are known to extend uninterrupted over the dome. Aquifers 3b, 4, and 5 intersect the upper salt stock, and 3b may be in direct hydrologic connection with the water-bearing limestone caprock of the dome. Impermeable clay and silt beds occur between the aquifers and prevent cross-flow between aquifers. Static water levels of the five major aquifer units

in the immediate Tatum Dome area vary between 48 and 65 meters above mean sea-level and Aquifer 5 stands at least 4.5 meters higher than any of the other units.

Aquifer 5 is brine-saturated and is used for disposal of oil field brines several miles to the southwest of the dome. The overlying aquifers contain fresh water. Well inventories within an eight kilometer radius of the site show supply wells only in the "local" aquifer and Aquifer 1. Estimated rates of movement of water in Aquifers 3, 4, and 5 are less than 3.5 meters per year. The highest rate of movement, 50 meters per year, is estimated for Aquifer 2a (Reference 1). Direction of water movement varies for each aquifer, but is generally northeast or southwest.

The detailed geologic and hydrologic setting of Tatum Dome and environs is described in the Dribble Technical Letter series of the U. S. Geological Survey (USGS).

2.2 PRE-SHOT GROUND-WATER SAFETY

The following is a brief chronological review of H-NSC pre-shot evaluations and recommendations concerning the ground-water safety of the Salmon Event.

A) "RADIOACTIVE HAZARD EVALUATION, HYDROGEOLOGIC PROGRAM, PROJECT DRIBBLE," OCTOBER 4, 1962: HAZLETON-NUCLEAR SCIENCE CORPORATION.

This initial submittal defined the ground-water safety problems associated with Project Dribble; briefly, these are chemical and radiologic contamination and disruption of flow of aquifers intersecting and overlying Tatum Dome. The proposed hydrologic data collection program (Reference 2) was reviewed. The program appeared to be adequate to answer most of the hydrogeologic questions which might arise; however, it was concluded that additional attention should be given to the possible needs of a post-shot monitoring surveillance program as well as the remedial procedure requirements which might become necessary. Recommendations were made to increase the overall effectiveness of the proposed hydrologic program and for a monitoring program to be initiated if radioactivity escaped the salt dome.

B) "DRIBBLE CALCULATIONS FOR SEVERAL CONDITIONS OF AQUIFER CONTAMINATION AND TRANSPORT OF RADIOACTIVITIES", OCTOBER 19, 1962: HAZLETON-NUCLEAR SCIENCE CORPORATION.

Evaluation was made of the hazard to ground-water supplies arising from the introduction of explosion-produced Sr^{90}, Cs^{137}, Cl^{36}, and S^{35} into aquifers intersecting and overlying Tatum Dome. It was concluded that under the most extreme conditions of nuclide migration, dissolution, and transport by ground water, that the probability of significant contamination of ground water beyond 1.7 kilometers of the

detonation site was very small. In addition, the calculated rates of contaminant movement would allow sufficient time for the instigation of appropriate remedial measures.

C) "EVALUATION OF THE HYDROLOGIC PROGRAM PROJECT DRIBBLE", MAY 8, 1963: HAZLETON-NUCLEAR SCIENCE CORPORATION: S. N. DAVIS, CARROLL E. BRADBERRY AND ASSOCIATES INC.

Current USGS technical letters were reviewed. The conclusions of the H-NSC report of October 4, 1962 were re-examined. Most of the original conclusions remained essentially unmodified and several statements were made to clarify the previous conclusions in the light of new data available. In addition, several lines of evidence which would indicate possible shot-induced contamination of aquifers were summarized and it was suggested that a large-scale monitoring program should not be initiated until radionuclide contamination of aquifers was detected.

D) "PRODUCTION AND GROUND-WATER TRANSPORT OF RADIONUCLIDES, PROJECT DRIBBLE, SALMON EVENT, MAY 8, 1963, JOHN V. A. SHARP, HAZLETON-NUCLEAR SCIENCE CORPORATION.

The H-NSC report of October 19, 1962 was revised utilizing current USGS data and refined prediction methodologies. The following was concluded. In the unlikely event that fission and neutron-activation nuclides escaped the salt mass and were incorporated in the aquifers subsequent ground-water transport of these nuclides would be restricted to several

thousand feet (~700 meters) prior to radioactive decay to less than maximum permissible concentrations (MPC_W). Recommendations were made for collection of additional data required for post-shot safety evaluation in the event that explosion nuclides entered the aquifers.

E) INPUT FOR THE FINAL OPERATIONAL SAFETY PLAN, PROJECT DRIBBLE, SALMON EVENT, JUNE 22, 1964, HAZLETON-NUCLEAR SCIENCE CORPORATION.

The report corresponds to parts of Sections 2.7 and 3.9 of the Operational Safety Plan, Project Dribble-Salmon Event, July, 1964. The body of the report is included here as it is a concise summary of H-NSC pre-shot evaluations and post-shot activities concerning ground-water safety.

Gro' -Water Contamination Predictions

Radionuclides released by the Salmon event are expected to be completely contained within the salt mass of Tatum Dome. In the unlikely event that contaminants are not confined to the salt mass and are introduced into aquifers overlying or intersecting Tatum Dome, it is expected that contaminant movement within aquifers will be small.

Present knowledge of the Tatum ground-water system indicates that velocities of ground-water movement are low. In addition, ion exchange characteristics of the aquifers will significantly retard the movement of most radionuclides with respect to the conveying ground water. The combination of low ground-water velocities, radioactive decay, and radionuclide sorption would probably limit movement of contaminants to a maximum of a few thousand feet of the point of introduction before reduction to acceptable concentration.

Predicted explosion effects indicate that the possibility of cross-aquifer flow of poor quality water and brines from the Caprock and Aquifers 4 and 5 into overlying aquifers containing potable water is not likely.

Although contamination of ground water in the vicinity of Tatum Dome as a result of Project Dribble is probably remote, ground-water studies completed at this site have defined the characteristics of the aquifer systems and any instance of alleged or real ground-water contamination can be properly evaluated.

In addition, if post-shot information suggests the possibility of contamination, the basic hydrogeologic data from the Dribble Site would provide a sound basis for designing a monitoring system and remedial measures.

Post-Shot Ground-Water Contamination Evaluation

To assure public safety regarding ground-water supplies in the vicinity of the shots at Tatum Dome several lines of evidence can be utilized to evaluate the possibility of ground-water contamination. These include:

a. anomalous seismic response indicating extensive fracturing,

b. discovery in post-detonation drilling of unexpectedly extensive rubble chimney or fractures with radionuclides,

c. evidence of stemming, casing, and grout failure of a type which might allow injection of radionuclides into an aquifer,

d. evidence of rapid changes in water levels or piezometric surfaces indicating rapid movement of ground water,

e. radiochemical analysis showing high radionuclide content in water from close-in observation wells, and

f. increased radioactivity levels in post-detonation gamma-ray logging of close-in observation wells.

In addition to these indicators, pre-shot and post-shot sampling analysis of ground water from wells, springs, and water use points in the vicinity of Tatum Dome will be of value in appraising the extent of ground-water contamination. If any information suggests aquifer contamination, a comprehensive plan of evaluating the extent and degree of contamination and possible corrective actions can be formulated. The expected slow-rate of movement of contaminants will allow sufficient time to institute appropriate studies and action.

F) ORAL PRESENTATIONS

In addition to the submittals cited above, H-NSC personnel participated in several meetings regarding the Dribble Project and presented oral statements concerning ground-water contamination and safety aspects of the Salmon Event.

CHAPTER 3

ANALYSIS AND DISCUSSION

3.1 POST-SHOT GROUND-WATER SAFETY

Analysis of current post-shot data indicates that radionuclides from the Salmon explosion were essentially contained within the salt mass of Tatum Dome. Radionuclides have not been detected in the subsurface beyond the immediate standing cavity and large-scale explosion-induced movement of nuclides appears to have been very limited. Neither hazardous radiocontamination nor radioactivity significantly above pre-shot recorded levels as a direct result of the explosion was detected in the aquifers.

A review and interpretation follows of shot and post-shot data which concern ground-water safety associated with the Salmon Event.

3.2 CONTAMINATION OF AQUIFERS

3.2.1 Re-entry Drilling. A rubble chimney was not formed by the explosion and a stable explosion cavity was penetrated by two drill holes from the surface. All evidence reported from this program indicated that ground water had not moved into the explosion chamber from aquifers intersecting or overlying Tatum Dome (Reference 3). Cores and radioactivity logs showed that explosion radionuclides were confined to the

cavity and to the salt matrix immediately surrounding the cavity (Reference 3). All evidence suggested the re-entry and emplacement holes were adequately cased and grouted and that aquifer water migration in the annular space between the holes and casing was virtually nonexistent. Future escape of nuclides still present within the cavity to contaminate overlying aquifers via the emplacement or re-entry holes was considered very unlikely unless destruction of hole integrity results from future construction or testing operations.

3.2.2 Ground-Water Sampling. Post-shot sampling of Aquifers 1, 2a, 2b, 3, and the caprock was conducted in various wells within a 1.9 kilometer radius of ground-zero. The USGS performed radiologic analyses of splits from these samples (References 4 and 5). The procedures employed by the USGS in making the analyses allowed detection of tritium concentrations to about 4×10^{-6} µc/ml, several orders of magnitude or more above probable background concentrations in ground water.[1] The USGS did not detect tritium in any of the samples processed. Analyses for gross beta activity as strontium-90 ranged from undetected to 2.6×10^{-8} µc/ml. None of the samples recorded any radioactivity attributable to the Salmon detonation within the

[1] Background tritium levels reportedly are less than ten tritium units (one tritium unit = 3.24×10^{-9} µc/ml).

limitations of the analytic procedures employed. The post-shot radioactivity observed was well within the range of levels measured in pre-shot samples gathered from the same aquifers in the immediate area. From the above it was concluded that the aquifers sampled probably were not contaminated as a direct result of the Salmon event. However, qualification is necessary in that (1) the aquifers may have been sampled before the considered nuclides had migrated to the sampling points, or; (2) the analytic procedures employed may not have sufficient sensitivity or versatility to detect extremely low concentrations of explosion radionuclides.

3.2.3 Gamma-Radioactivity Logging. Post-shot gamma-radioactivity measurements were logged by the USGS in 11 wells in the immediate area of Tatum Dome within 30 days after the nuclear detonation. Several test wells within a 2.5 kilometer radius had been logged prior to the event. Direct comparison of pre- and post-shot logs (Reference 6) indicated no detectable increase in radioactivity as a result of the shot. Post-shot logs from the other wells were within the normally expected levels of naturally occurring radiation activity. This provided additional evidence that the aquifers probably were not contaminated as a result of the Salmon event. However, the possibilities exist that: 1) explosion radioactivity may

not have reached the measured intervals at the time of post-shot logging, or; 2) the detection equipment may have insufficient capability to record explosion-derived radioactivity present in the logged intervals.

3.2.4 Surface-Water Sampling. The U. S. Public Health Service carried out a pre- and post-shot surface water sampling and radiochemical analysis program in a large area around the Salmon site. Through July 26, 1965 no increase in radioactivity over observed pre-shot background levels has been recorded in any of the samples analyzed (Reference 3). It was concluded that contamination of surface waters by radionuclides resulting from the Salmon Event probably did not occur.

3.3 DISRUPTION OF AQUIFERS

3.3.1 Aquifer Response. Water level measurements were taken in wells at various distances from surface zero and the results have been reported by the USGS (Reference 8).

A general rise of 5 to 8 feet with a maximum deflection of about 15 feet in water level was observed immediately after the detonation and cyclic fluctuations were recorded for some time before re-stabilization occurred.

The response of aquifers to explosion shock waves in general is difficult to interpret and the effects observed at Salmon do not indicate conclusively whether contamination or damage

to any of the aquifers occurred. However, in reporting the aquifer response water level fluctuations, no significant permanent changes in re-stabilized hydrostatic heads were recorded in any of the aquifers examined. From this it might be inferred that shot-induced damage to aquifers, possibly resulting in major aquifer cross-flow and brine contamination, did not occur.

3.3.2 Surface-Flow Response. Small increases in stream discharge volumes were recorded for a short time following the Salmon Event and re-stabilization to normal levels occurred in about 20 days. The increased volumes probably were supplied from the shallow aquifers present within the individual and combined drainage basins. No inference regarding ground-water safety is drawn from the data reported (Reference 9).

CHAPTER 4

GROUND-WATER SAFETY RECOMMENDATIONS

4.1 AQUIFER MONITORING

Radioactivity in aquifers as a direct result of the Salmon explosion has not been observed during the early post-shot period. However, the limited time period and scope of post-shot radioactivity monitoring of aquifers places uncertainty on the exclusion of radionuclides from the aquifers by explosion action. To better establish the exclusion of nuclides and to provide assurance of public safety, the post-shot radiologic characteristics of the aquifers should be monitored on an occasional but continuing basis for a period of years. The exclusion of radionuclides can never be absolutely confirmed by practical surveillance measures, but it is considered desirable to have at least several years of continuing monitoring experience to rely upon. The following program is accordingly recommended:

1) annual sampling for three years accompanied by radiologic analyses of fluids collected from selected water points within a two kilometer radius of surface zero, the requirement for subsequent sampling to be determined at the end of the three-year period;
2) maintenance on a standby basis of all pre- and post-shot hydrologic test wells at the Salmon site to

allow their use for aquifer sampling and possible remedial measures should any contamination be detected at a future date, and

b) in the event of detection of explosion radioactivity in aquifers, modify the monitoring program as appropriate and prepare and implement remedial measures as required.

REFERENCES

1. E. J. Harvey and R. V. Chaffin; "Geology and Hydrology of the Tatum Salt Dome, Lamar County, Mississippi," April 29, 1963, Technical Letter-Dribble 34; U. S. Geological Survey; Unclassified.

2. J. W. Lang; Hydrologic Studies, Project Dribble, Tatum Salt Dome," November 24, 1961; Technical Letter-Dribble 9; U. S. Geological Survey; Unclassified.

3. L. J. Yelinek, Site Manager-Project Dribble; Letters to J. E. Reeves, Manager, NVOO, AEC, Las Vegas, Nevada; Subject: "Project Dribble Weekly Activities Reports," April 5, 1964 to July 30, 1965; Unclassified.

4. V. J. Janzer and S. J. Rucker; "Radiochemical Analyses of Water Samples Collected Postshot in the Vicinity of Tatum Dome, Mississippi," Feb. 8, 1965; Technical Letter-Dribble 42; U. S. Geological Survey; Unclassified.

5. V. J. Janzer, B. P. Robinson and S. J. Rucker; "Radiochemical Analyses of Water Samples Collected Postshot in the Vicinity of Tatum Dome, Mississippi," May 28, 1965; Technical Letter-Dribble 44; U. S. Geological Survey; Unclassified.

6. C. M. Bunker and W. A. Bradley; "Subsurface Gamma-Radioactivity Measurements After Salmon Event Project Dribble, Lamar County, Mississippi," June 29, 1965; Technical Letter-Dribble 44; U. S. Geological Survey; Unclassified.

7. M. S. Garber and W. E. Hale, USGS, Denver, Colorado; Letter to F. A. Linville, Technical Director, Holmes and Narver, Inc., Las Vegas, Nevada, Subject: "Aquifer-Response Measurements for the Salmon Event Tatum Dome, Mississippi," March 17, 1965; Unclassified.

8. C. P. Humphreys, Jr., and R. E. Taylor; "Streamflow in Lower Little Creek Basin Affected by the Salmon Event, Lamar County, Mississippi," March 26, 1965; Technical Letter-Dribble 43; U. S. Geological Survey; Unclassified.

TECHNICAL AND SAFETY PROGRAM REPORTS SCHEDULED FOR ISSUANCE BY AGENCIES PARTICIPATING IN PROJECT DRIBBLE

SAFETY REPORTS

Agency	Report No.	Subject or Title
USWB	VUF-1020	Weather and Surface Radiation Prediction Activities
USPHS	VUF-1021	Final Report of Off-site Surveillance
USBM	VUF-1022	Pre and Post-Shot Safety Inspection of Oil and Gas Facilities Near Project Dribble
USGS	VUF-1023	Analysis of Geohydrology of Tatum Salt Dome
USGS	VUF-1024	Analysis of Aquifer Response
REECo	VUF-1025	On-Site Health and Safety Report
RFB, Inc.	VUF-1026	Analysis of Dribble Data on Ground Motion and Containment - Safety Program
H-NSC	VUF-1027	Ground Water Safety
FAA	VUF-1028	Federal Aviation Agency Airspace Advisory
H&N	VUF-1029	Summary of Pre and Post-Shot Structural Survey Reports
JAB	VUF-1030	Structural Response of Residential-Type Test Structures in Close Proximity to an Underground Nuclear Detonation
JAB	VUF-1031	Structural Response of Tall Industrial and Residential Structures to an Underground Nuclear Detonation.

NOTE: The Seismic Safety data will be included in the USC&GS Technical Report VUF-3014

TECHNICAL REPORTS

Agency	Report No.	Subject or Title
SL	VUF-3012	Free-Field Particle Motions from a Nuclear Explosion in Salt - Part I
SRI	VUF-3013	Free-Field Particle Motions from a Nuclear Explosion in Salt - Part II
USC&GS	VUF-3014	Earth Vibration from a Nuclear Explosion in a Salt Dome
UED	VUF-3015	Compressional Velocity and Distance Measurements in a Salt Dome

LRL	VUF-3016	Design and Operation of a Chemical Processing Plant for Controlled Release of a Radioactive Gas from the Cavity of a Nuclear Explosion in Salt
LRL	PNE-3002 *	Response of Test Structures to Ground Motion from an Underground Nuclear Explosion
SRI	VUF-3017	Feasibility of Cavity Pressure and Temperature Measurements for a Decoupled Nuclear Explosion
LRL	VUF-3018	Background Engineering Data and Summary of Instrumentation for a Nuclear Test in Salt
WES	VUF-3019	Laboratory Design and Analyses and Field Control of Grouting Mixtures Employed at a Nuclear Test in Salt
LRL	VUF-3020	Geology and Physical and Chemical Properties of the Site for a Nuclear Explosion in Salt
EG&G	VUF-3021	Timing and Firing

* This report number was assigned by SAN

In addition to the reports listed above as scheduled for issuance by the Project DRIBBLE test organization, a number of papers covering interpretation of the SALMON data are to be submitted to the American Geophysical Union for publication. As of February 1, 1965, the list of these papers consists of the following:

Title	Author(s)	Agency(s)
Shock Wave Calculations of Salmon	L. A. Rogers	LRL
Nuclear Decoupling, Full and Partial	D. W. Patterson	LRL
Calculation of P-Wave Amplitudes for Salmon	D. L. Springer and W. D. Kurdlow	LRL
Travel Times and Amplitudes of Salmon Explosion	J. N. Jordan W. V. Mickey W. Helterbran	USC&GS AFTAC UED
Detection, Analysis and Interpretation of Teleseismic Signals from the Salmon Event	A. Archambeau and E. A. Flinn	SDC
Epicenter Locations of Salmon Event	E. Herrin and J. Taggart	SMU USC&GS
The Post-Explosion Environment Resulting from the Salmon Event	D. E. Rawson and S. M. Hansen	LRL
Measurements of the Crustal Structure in Mississippi	D. H. Warren J. H. Healy W. H. Jackson	USGS

All but the last paper in the above list will be read at the annual meeting of the American Geophysical Union in April 1965.

LIST OF ABBREVIATIONS FOR TECHNICAL AGENCIES

BR LTD	Barringer Research Limited Rexdale, Ontario, Canada
ERDL	Engineering Research Development Laboratory Fort Belvoir, Virginia
FAA	Federal Aviation Agency Los Angeles, California
GIMRADA	U. S. Army Geodesy, Intelligence and Mapping Research and Development Agency Fort Belvior, Virginia
H-NSC	Hazleton-Nuclear Science Corporation Palo Alto, California
H&N, INC	Holmes & Narver, Inc. Los Angeles, California Las Vegas, Nevada
II	Isotopes, Inc. Westwood, New Jersey
ITEK	Itek Corporation Palo Alto, California
JAB	John A. Blume & Associates Research Division San Francisco, California
LRL	Lawrence Radiation Laboratory Livermore, California
NRDL	U. S. Naval Radiological Defense Laboratory San Francisco, California
REECo	Reynolds Electrical & Engineering Co., Inc Las Vegas, Nevada
RFB, INC.	R. F. Beers, Inc. Alexandria, Virginia
SDC	Seismic Data Center Alexandria, Virginia
EG&G	Edgerton, Germeshausen & Grier, Inc. Las Vegas, Nevada
SL	Sandia Laboratory Albuquerque, New Mexico
SMU	Southern Methodist University Dallas, Texas
SRI	Stanford Research Institute Menlo Park, California
TI	Texas Instruments, Inc. Dallas, Texas
UA	United Aircraft El Segundo, California
UED	United Electro Dynamics, Inc. Pasadena, California
USBM	U. S. Bureau of Mines Washington, 25, D. C.
USC&GS	U. S. Coast and Geodetic Survey Las Vegas, Nevada
USGS	U. S. Geologic Survey Denver, Colorado
USPHS	U. S. Public Health Service Las Vegas, Nevada
USWB	U. S. Weather Bureau Las Vegas, Nevada

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1 Space Technology Labs. Inc., One Space Park, Redondo Beach, California For: Dr. Suer

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3 Nuclear Test Detection Office, Advanced Research Projects Agency, Department of Defense, Washington, D. C. 20301

5 Advanced Research Projects Agency, Department of Defense, Washington, D. C. 20301 For: Rudy Black

1 Mr. Wayne Everett Hall, U. S. Geological Survey, Div. of Experimental Geology, Dept. of Interior, Washington. D. C. 20242

2 Mr. Charles R. Gellner, U. S. Arms Control & Disarmament Agency, Dept. of State, Washington, D. C.

1 Institute for Defense Analysis, 1825 Connecticut Ave., N. W. Washington, D. C. Attn. Al Rubinstein

1 Shell Development Company, P. O. Box 481, Houston, Texas 77001 ATTN: Dr. Sidney Kaufman, Exploration Division

3 VELA Seismological Center, c/o Headquarters, USAF/AFTAC, Washington 25, D. C.

1 Lincoln Laboratories, Lexington 73, Massachusetts, Attn: Dr. P. Green

1 Vela Seismic Information Analysis Center, University of Michigan P. O. Box 608, Ann Arbor, Michigan

1 Edgerton, Germeshausen & Grier, Inc., Santa Barbara Laboratory P. O. Box 98, Goleta, Calif., 93017 Attn: M. B. Carpenter

10 U. S. Atomic Energy Commission, Division of Technical Information Service, P. O. Box 62, Oak Ridge, Tennessee 37831

1 U. S. Atomic Energy Commission, Division of Technical Information, Washington, D. C. 20545

1 U. S. Atomic Energy Commission, Division of Operational Safety, Washington, D. C. 20545

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